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A novel servo-driven dual-roller handrim wheelchair ergometer: comparison with a measurement wheel

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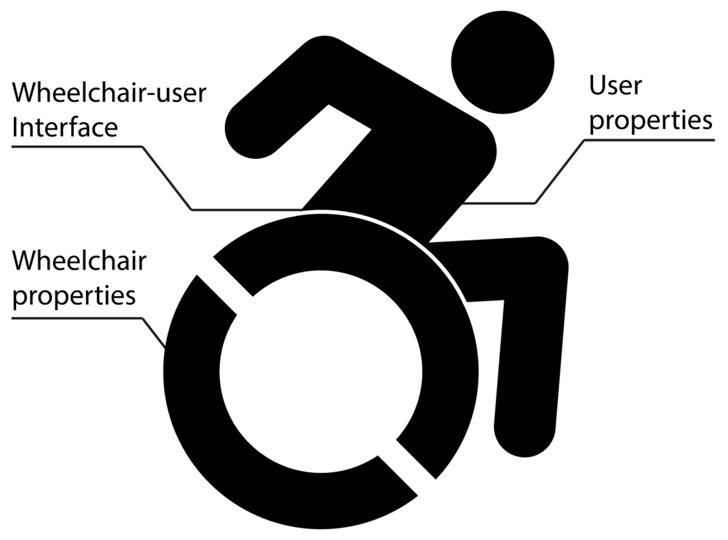
Background

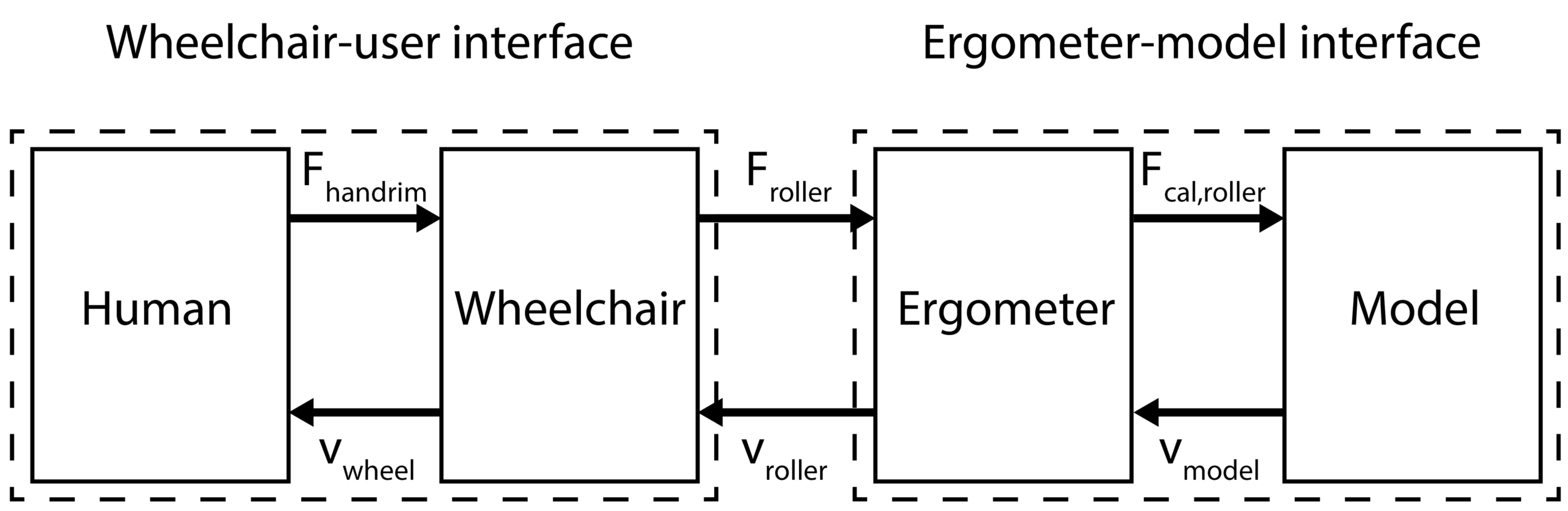
Measurement wheels allow for the collection of detailed information on propulsion technique. However, the wheels of the wheelchair need to be replaced, which alters the wheelchair-user interface (shown on the bottom-right). An ergometer allows for the collection of the same data without changing the wheelchair. A new computer-controlled ergometer is presented which allows for the collection of similar data through indirect measurements while providing a constrained and standardized environment.



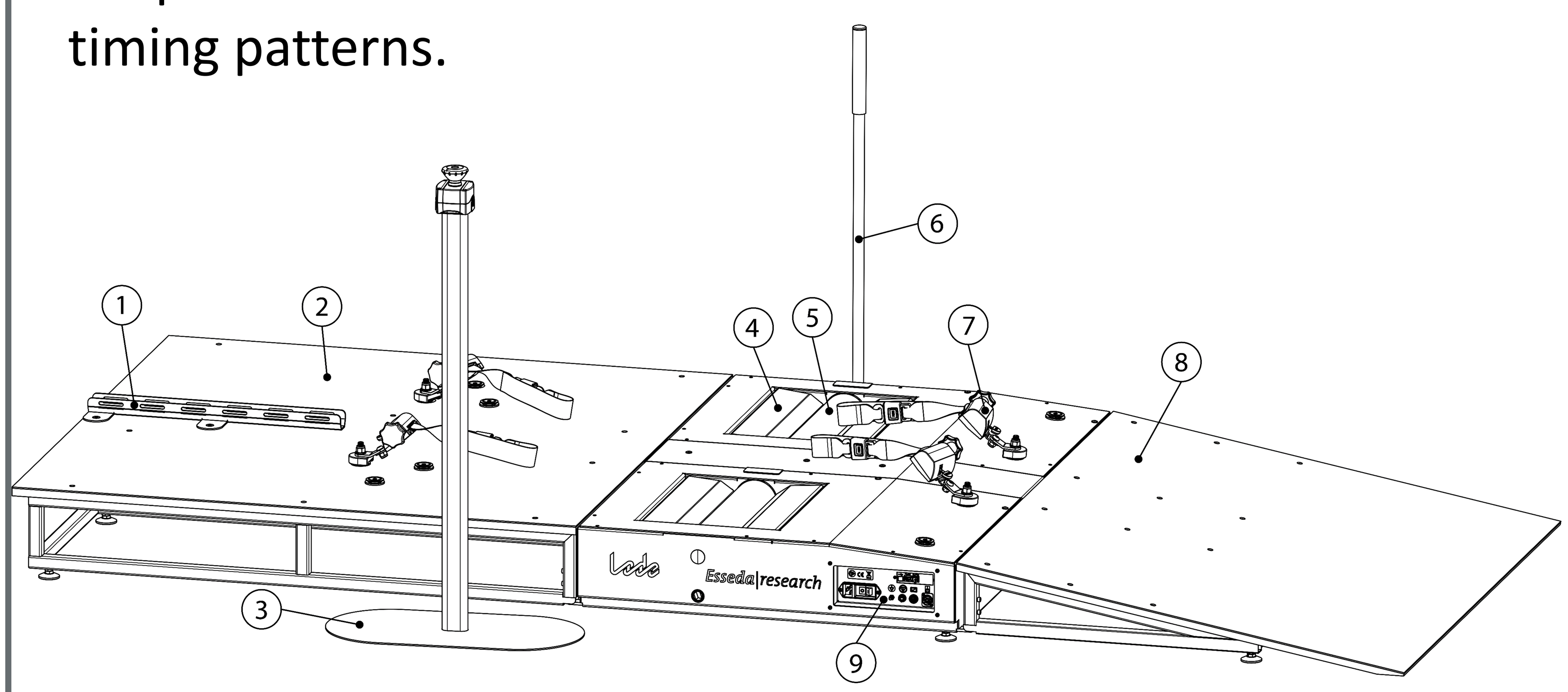
Goals:

The first objective is to provide a thorough description of the new wheelchair ergometer. The second objective is to compare results obtained with the ergometer with the gold standard in wheelchair research (measurement wheels).

Ergometer design



The ergometer (shown below) contains two servomotors, one for each rear wheel roller, that allow for the simulation of translational inertia and resistive forces as encountered during wheelchair propulsion based on force input (shown above) and a simple mechanical model of wheelchair propulsion. A load cell configuration for left and right roller allows for the measurement of effective user-generated torque and force on the handrim and the concomitant timing patterns.

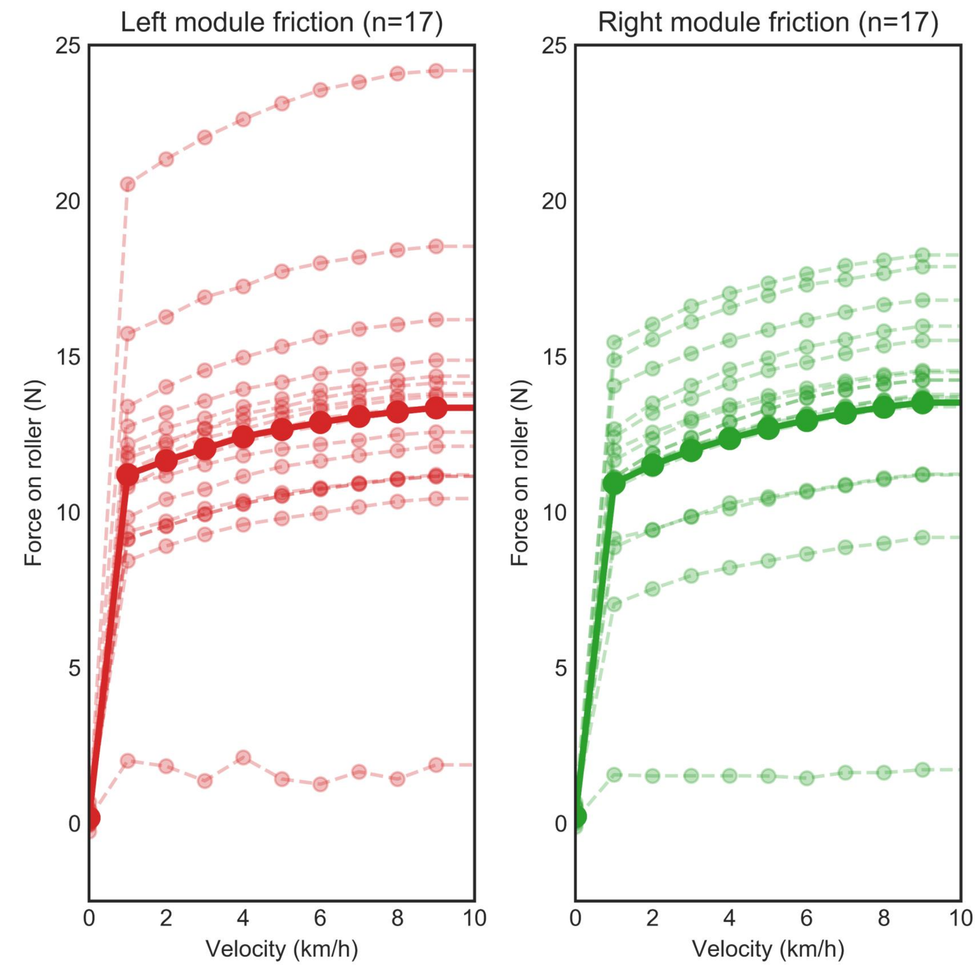


The Esseda wheelchair ergometer: 1. Wheeler extension; 2. Castor support board; 3. Emergency stop; 4: Alignment flaps; 5. Roller (2x); 6: Alignment handle; 7: Straps (4x); 8: Ramp; 9: Communication module

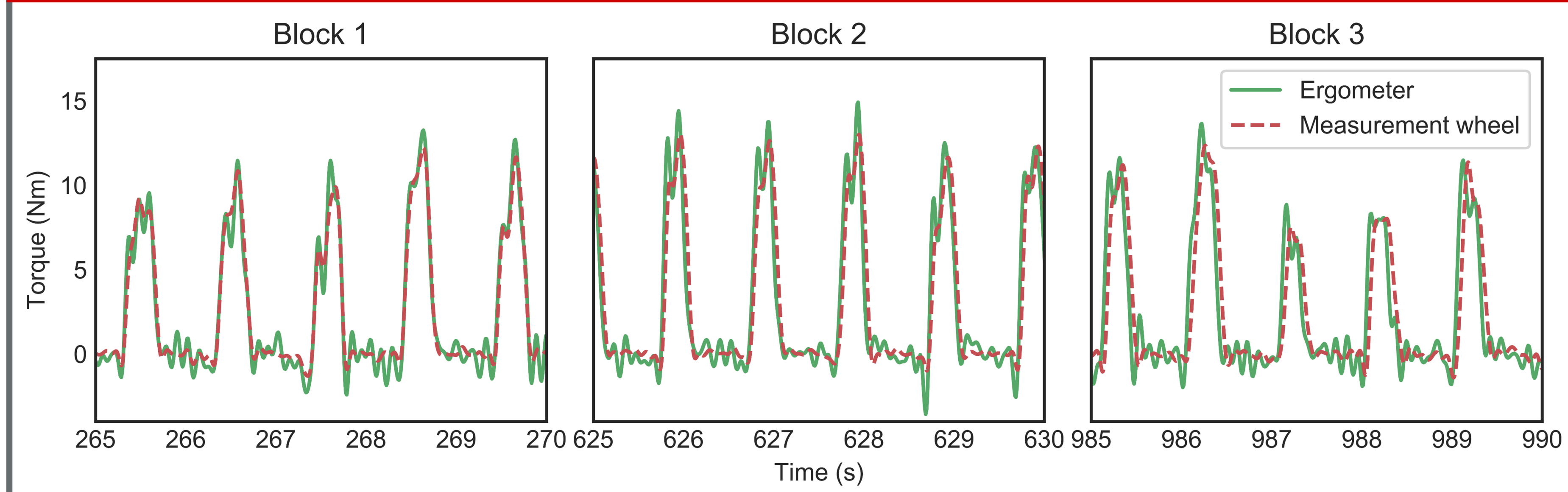
Calibrations

The ergometer needs to be calibrated before each trial to compensate for rolling- and internal friction (both static and viscous).

The calibration curves for seventeen participants are shown on the right. Exemplifying the need for individual calibrations.



Testing & Results



Seventeen able-bodied participants that were familiar with wheelchair propulsion propelled a wheelchair with a measurement wheel (Optipush) on the ergometer for three blocks of 4-minutes at 1.11 m/s. Data from the last minute were analysed in Python, assuming steady-state propulsion.

Common outcome from the measurement wheel were compared with the ergometer (figure above, table below). The ergometer data contained more noise but the discrete outcome measures all showed excellent (absolute) agreement based on their intraclass correlation coefficients.

Variable	Measurement wheel MEAN + SD	Ergometer MEAN + SD	Intraclass correlation (95% CI)
Push time (s)	0.32 (0.07)	0.32 (0.07)	0.99 (0.97-0.99)
Cycle time (s)	1.29 (0.54)	1.29 (0.54)	1.00 (1.00-1.00)
Push angle (deg)	66.59 (14.17)	66.24 (13.84)	0.98 (0.96-0.99)
Mean torque (Nm)	1.15 (0.30)	1.28 (0.27)	0.91 (0.53-0.97)
Mean power (W)	4.24 (1.11)	4.68 (1.00)	0.92 (0.61-0.97)
Mean torque p.p (Nm)	4.82 (1.30)	5.06 (1.41)	0.98 (0.62-0.99)
Peak torque p.p (Nm)	8.33 (2.64)	9.08 (2.86)	0.95 (0.17-0.99)
Mean power p.p (W)	17.78 (4.78)	18.52 (5.13)	0.98 (0.76-1.00)
Peak power p.p (W)	31.06 (10.01)	33.46 (10.74)	0.96 (0.34-0.96)

Conclusions

Under present conditions, the ergometer and the gold standard (measurement wheel) show excellent agreement. This implies that the ergometer can be used in the same manner as measurement wheels without the need to adjust the wheelchair-user interface. Further research on measurement accuracy in different conditions is needed.

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